National Aeronautics and Space Administration

Final Presenters
Aeronautics Student Forum Summer 2009

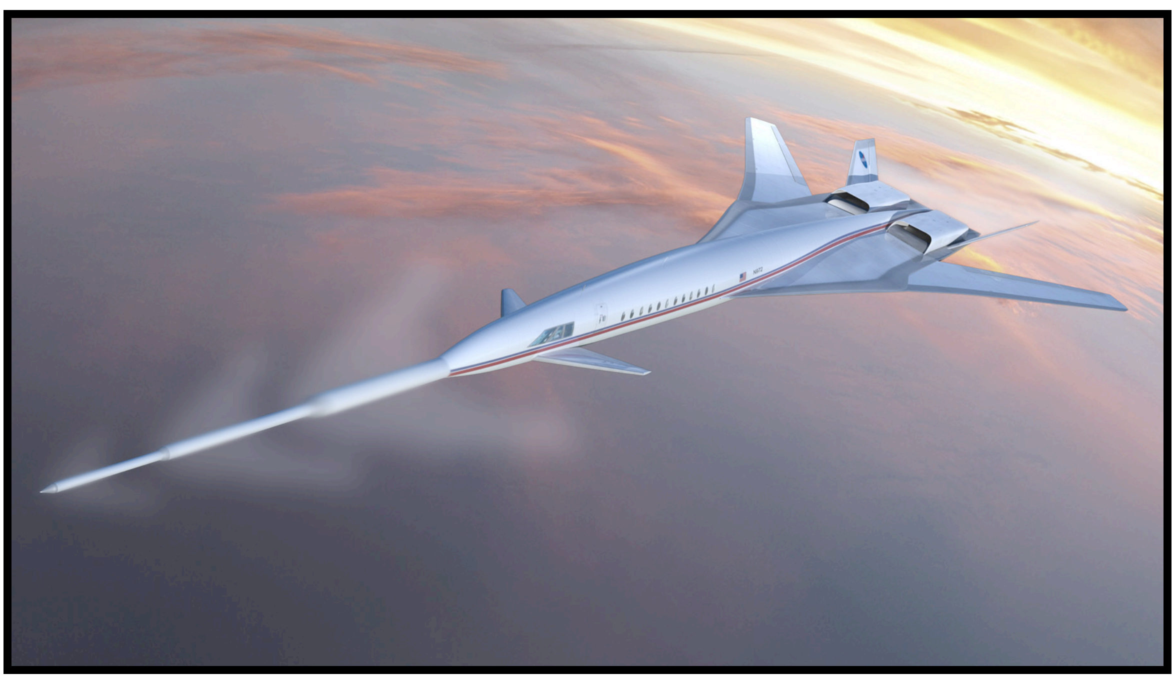
Student Research in Aeronautics and Related Disciplines

Hosted by the
Aeronautics Research Directorate
NASA Langley Research Center

July 30, 2009
9 am to Noon
Pearl Young Theater

Order of Presentations

Research and Technology Directorate
Science Directorate
Systems Analysis & Concepts Directorate
Systems Engineering Directorate
Aeronautics Research Directorate



Research and Technology Directorate

Turbulence Modeling Approaches for Flow Control Problems with Curvature

Student: Shelly Jiang, Senior, University of Michigan – Ann Arbor

Mentor: Christopher Rumsey
Computational AeroSciences Branch

In AIAA 98-2554, A. Hellsten proposed a rotation and curvature (RC) correction to Menter's k-omega SST turbulence model. My project applies the improved SST-RC turbulence model to flow control problems with curvature. The SST-RC model has been implemented in both CFL3D and FUN3D. Test cases on the SoMellor curved duct and the Lockheed circulation control airfoil with varying blowing coefficients are run using these CFD flow solvers. The results are compared to those with other turbulence models and experimental data. The accuracy of the SST-RC model for these applications is analyzed and recommendations for future work are given.

Surface Preparation and Characterization of Aerospace Structural Components

Student: Martina S. List, Junior, Northeastern University

Mentors: Marcus A. Belcher, John W. Connell, Jeffrey A. Hinkley
Advanced Materials and Processing Branch

This research supports the Aircraft Aging and Durability Project (Aviation Safety Program). Adhesive bonds are critical to the integrity of built-up structures. Disbonds can often be detected but the strength of adhesion between surfaces in contact is not obtainable without destructive testing. The number one problem with bonded structures is surface contamination and standard surface preparation techniques are not ideal because of variations in their application. However, the use of a Nd:YAG laser offers a promising way to both clean a surface prior to bonding as well as provide a bond-promoting surface with high reproducibility and greater precision.

Automating Surface Acoustic Wave research

Student: Bryan E. Greenly, Junior, Delaware State University

Mentor: William C. Wilson, Nondestructive Evaluation Sciences Branch

Surface acoustic wave (SAW) devices are currently being evaluated as wireless microsensors for applications in the Integrated Vehicle Health Monitoring (IVHM) System. SAW devices utilize the piezoelectric properties of quartz and other materials to signal changes in physical conditions, such as temperature, chemical, and torque. It is desirable to develop an automated system of collecting data in order to analyze characteristics of SAW devices that will be used for IVHM. A LabView VI has been created that will control a network analyzer attached to a test probe station, and then collect data for the analysis of SAW device performance.

Control characteristics in transport aircraft

Student: Joseph Thompson, Graduate Student, University of Alabama at Birmingham

Mentor: Dr. Neal T. Frink, Ph.D.

Configuration and Aerodynamics Branch

The focal point of my research is the study of static and dynamic stability and control characteristics in transport aircraft. The primary goal is to obtain a better understanding of the flight characteristics of damaged or upset aircraft. The objective of this work is to assess the predictive capability of USM3D for modeling the dynamic stall and post-stall conditions in transport aircraft, with an ultimate goal of developing an integrated system to train pilots on how to manage upset conditions that may lead to a loss-of-control (LOC) incident. The data acquired can also be used to create a database that can be incorporated into the aircraft's flight management system to help assess, warn and manage a LOC event.

Aerodynamics: Hypersonics

Student: Thomas Lambert, Senior, Carnegie Mellon University

Mentor: Victor Lessard, Aerothermodynamics Branch

The objective of this project is to explore a computational fluid dynamics (CFD) overset meshing technology to study surface heating augmentation caused by cavities on the heat shield of the Crew Exploration Vehicle (CEV) at hypersonic speeds. This project will utilize a combination of PSU Applied Research Laboratory overset codes, SUGGAR and DiRTlib, along with NASA's Fully Unstructured Navier-Stokes flow code, FUN3D to explore the validity of overset unstructured meshes for aerothermodynamic calculations at hypersonic speeds. Computed aerodynamics and aeroheating results, utilizing different types of overset unstructured meshes, will be compared with calculations carried out by NASA's LAURA code on a non-overset structured grid system.

The Propulsion-Airframe Integrated Scramjet: Access to Space

Students:
Melissa Street, Junior, Washington State University
Andrea Dickason, Junior, University of North Dakota

Mentor: Troy Middleton, Hypersonic Airbreathing Propulsion Branch,

Currently, propulsion-airframe integrated scramjets are one of the most promising airbreathing propulsion systems for access to space. Integration of the propulsion system with the airframe of the vehicle uses the forebody surface of the airframe to direct the airflow into the scramjet engine. The air ingested by the engine is then reacted with fuel in the scramjet combustor and exhausted along the aft-body of the airframe, creating thrust. This presentation will discuss some of the key components of the scramjet engine, the capabilities and limitations of the scramjet engine, and the current state of the art in scramjet propulsion.

A New Approach to Coherent Anti-Stokes Raman Spectroscopy

Student: Jeff Wheeler, Junior, Whitworth University

Mentors: Sarah Tedder, Dr. Paul Danehy
Advanced Sensing and Optical Measurements Branch

Coherent Anti-Stokes Raman Spectroscopy (CARS) is a laser-based measurement system that can be used to study the properties of supersonic combustion gas flows. CARS can measure temperature and species concentration at points inside of a high temperature flow to aid in understanding the fundamental properties of the flow. Currently, the Advanced Sensing and Optical Measurement Branch is developing an improved CARS technique that will allow the simultaneous examination of more gas species. These species will be examined by using a spectrally broader laser than previous CARS systems.

Modeling Laminar and Turbulent Flow over a Flat Plate Using Adjoint Based Adaptation

Student: Julie C. Andren, Senior, Massachusetts Institute of Technology

Mentor: Dr. Michael A.Park,
Computational AeroSciences Branch

Manually creating a grid for accurate fluid flow simulation is an extremely difficult task. Adjoint (output) based grid adaptation is pursued to automatically generate grids that lead to accurate simulation results. Laminar and turbulent boundary layers over a range of Reynolds numbers are studied using both uniformly structured and adapted grids to determine the validity of the adaptive method for a flat plate. It is shown that uniformly structured grids currently provide more accurate results so the adaptation is restricted near solid walls. In the future, the information on the adjoint solver that is obtained for a flat plate will be extended to more complicated geometries.

Development of a semi-empirical model to predict the acoustic impedance of a metal foam

Student: Brendan Bialy, Senior, Clarkson University

Mentor: Dr. Carl Gerhold, Aeroacoustics Branch

Reduction of aircraft noise is an important element of NASA's Aeronautics mission. The purpose of this project is to investigate material suitable for mounting near the fan axial plane in engine nacelles, with potential to significantly reduce sound radiated from the engine. Tests conducted with a normal incidence impedance tube are used to determine characteristic impedance and propagation constant spectra for six types of metallic foam. Semi-empirical models are developed to determine characteristic impedance and propagation constant spectra as a function of air density and flow resistivity. These models will be used to support aircraft engine noise reduction investigations.

Materials Research: Polyimides for aircraft and spacecraft

Student: Brad Atkins, Senior, Rhodes College

Mentors: John Connell, Chris Wohl
Advanced Materials and Processing

Polyimides possess excellent mechanical and thermal properties. Many species of the siloxane class exhibit exceptionally low surface energies. Combined, these materials can be used in a wide range of applications by creating light-weight thin film coatings to prevent the adhesion of particulate matter on surfaces. Potential applications include: minimizing accumulation of water on aircraft thereby significantly reducing the risk of icing and fogging and protecting future lunar transport vehicles from the hazardous lunar regoltih. Our research focuses on examining how surface adhesion mitigation, mechanical properties, and transparency of polyimide siloxane films are affected by chemical composition and surface topographic modification.

Materials Research: Boron nitride nanosheets

Student: Tiffany Williams, Graduate Student, Cornell University

Mentors: Dr. John Connell, Dr. Yi Lin
Advanced Materials and Processing

This project is concerned with the synthesis and characterization of bimetallic nanoparticle-decorated carbon nanotubes and the formation of hexagonal boron nitride nanosheet dispersions in various solvents. Characterization via various microscopic and spectroscopic methods will provide information about the morphological, physical, and chemical properties of these materials. These materials are anticipated to exhibit unique combinations of mechanical, electrical, and thermal properties, which would render them useful for potential aerospace applications.

<u>S</u>emi<u>S</u>pan <u>S</u>uper<u>S</u>onic <u>T</u>ransport <u>A</u>ctive <u>C</u>ontrols <u>T</u>estbed (S^4T ACT)

Student: Christie Funk, Graduate Student, Embry-Riddle Aeronautical University

Mentors: Dr. Walter Silva and Mr. Boyd Perry, III, Aeroelasticity Branch

Aeroelasticity is the mutual interaction of inertia, aerodynamic and elastic forces acting on a flight vehicle. Phenomena such as flutter, gust loads, and ride quality all depend on the unique characteristics of a particular configuration. The Aeroelasticity Branch is currently testing in the Langley Transonic Dynamics Tunnel (TDT) an aeroelastically scaled, supersonic-transport-type model, the S^4T. The purpose of testing is to investigate lessening the detrimental effects of these phenomena through the use of active controls. This presentation will present an overview of the TDT and the S^4T and discuss the process of using active controls to optimize aircraft aeroelastic performance.

Supersonics Aeroelasticity Research

Student: Raul Telles, Graduate Student, Virginia Tech

Mentor: Dr. Walter A. Silva, Aeroelasticity Branch

An important component in the on going research at NASA is the Supersonics Program. The Aeroelasticity Branch is currently conducting an aeroelastic analysis and testing of the SemiSpan SuperSonic Transport (S4T) wind-tunnel model. The goal of this project is to perform a wide range of validations of experimental systems and analytical models. Validation of experimental systems includes analysis of hardware used for testing the structural properties of the S4T. Validation of analytical models includes additional analyses based on recent wind-tunnel model modifications. Both of these tasks will be essential towards a better understanding and prediction of the aeroelastic response of the S4T wind-tunnel model.

Supersonics Modeling using MATLAB

Student: Matthew Vaughan, Senior, Massachusetts Institute of Technology

Mentor: Dr. Walter A. Silva, Aeroelasticity Branch

Currently under development are control laws for the Supersonic Semi-span Transport (S4T) that provide flutter suppression, gust load alleviation, and ride quality control. The goal of this project is to assist in the development of high fidelity control laws by using the MATLAB System Identification Toolbox as well as NASA-developed software to create linear plant models of the S4T. Initial results have yielded moderately accurate models, which are tested by comparing simulated data using the models to wind tunnel data. Future investigation will determine the limitations of linear modeling as well as the nature of the nonlinearity within the S4T.

Supersonics Modeling using CFL3D

Student: Jeremy Maunus, Graduate Student, Boston University

Mentor: Dr. Walter Silva, Aeroelasticity Branch

Under the auspices of the Fundamental Aeronautics Program's Supersonics Project an aeroservoelastic semispan wind-tunnel model is being tested in the Transonic Dynamics Tunnel, here, at NASA Langley Research Center. The model, referred to as the Supersonic Semispan Transport (S^4T) Active Controls Testbed (ACT), has three active control surfaces including, aileron, horizontal tail, and an all-movable ride control vane. Here, CFL3D, a computational fluid dynamics code, is used to conduct dynamic aeroelastic analysis of the S^4T model. Namely, flutter conditions (dynamic pressures and Mach numbers) are investigated by examining two simulation versions of the model and compared to experimentally determined data.

Flow Visualization for Aeroelastic Research

Student: Karan Arora, Senior, Rutgers University

Mentor: Dr. Jennifer Heeg, Aeroelasticity Branch

Measurement of structural dynamic and aeroelastic properties require special instrumentation considerations. These considerations include obtaining data at speeds fast enough to examine structural dynamic frequencies and adapting techniques and equipment to operate in specialized test facilities such as the Transonic Dynamics Tunnel. The objective of the current project is to evaluate optical methods for measuring aeroelastic model properties in the wind tunnel. The properties of interest include off-body unsteady flow field measurements and shock oscillations. The approach taken is to improve upon an existing shadowgraph system and evaluate modern techniques.

Did not present, but had a poster in the hallway:

Thermal Gravimetric Analysis of Ceramic Matrix Composites
Student: Jay Bumgarner
Sophomore, West Virginia University
Mentor: Wallace Vaughn
Advanced Materials and Processing Branch

Ceramic matrix composites are made by bonding ceramic fibers, typically in the form of woven fabric, together with a ceramic matrix. These materials have the ability to retain their mechanical properties up to 5000 °F, depending on specific composite compositions. The purpose of this project is to observe the oxidation and mass loss rates of CMCs in high-temperature oxidizing environments, by means of thermal gravimetric analysis. Thermal gravimetric analysis (TGA) is a technique that records changes in the mass of an object while it is heated. By observing CMC's reaction to simulated environments such as the ones in this experiment, we can collect preliminary data that can further prepare for the material's use in flight environments here on Earth as well as on Mars and other stellar environments.

Science Directorate

Joint Project: Using sramjet technology for space access

Students:

Chris Acuff, Junior, Mississippi State University
Kelcy Brunner, Junior, South Dakota School of Mines and Technology
Rita Groetz, Senior, University at Buffalo
Catherine Patrick, Senior, University of South Dakota

Mentors: Dr. Elizabeth Ward and Mr. Guy Kemmerly
Aeronautics Research Directorate & Science Directorate

With the successful flight of the X-43A scramjet at Mach 9.6 in 2004, the conceptualization of hypersonic air-breathing vehicles as a method of transportation proceeds closer to feasibility. To study the potential of scramjets, the engineering and scientific implications of scramjet use as a method of space access were explored by looking at a two-stage to orbit scenario. The chosen mission uses a preconceived reference vehicle to carry a payload into low earth orbit. Attention was focused on performing a variable weight analysis of the scramjet portion of the flight in MATLAB, studying the combustion chemistry and extrapolating the atmospheric effects associated with scramjet travel in the upper stratosphere.

Systems Analysis & Concepts Directorate

Immersive Virtual Human Environments (IVHE)

Students: Vivek Vittaldev, Graduate Student, Delft University of Technology
Steven Kelley, Graduate Student, Georgia Institute of Technology* not present

Mentors: Jeffrey Antol, Space Mission Analysis Branch
Dr. Douglas Stanley, National Institute of Aerospace

It is necessary to extract more information from an environment than what is feasible by human senses and to be able to facilitate the sharing of this information. We are working on a mobile robotic platform that integrates LiDAR, visual, and other scientific data for the purpose of creating immersive environments. This system will be extremely useful for airplane crash investigations. The platform can scan and recreate a full 3D model of the crash site with the scientific data assisting in finding the cause and searching for survivors. The LiDAR can be replaced by sonar for crashes over water bodies.

Concept studies for UAV VTOL

Student: Guillermo ‘Willie’ Costa, Junior, California State Polytechnic Institute & University, Pomona

Mentor: William Fredericks, Systems Analysis Branch

Student partner in the project: Alison Snyder, Junior, Ohio State University

Two concept studies of a new unmanned aerial vehicle (UAV) for Project Reimar have been created. The design mission for these vehicles calls for both long endurance and vertical takeoff and landing (VTOL) capability. To aid in performing these design studies a parametric, component-based modeling software called Vehicle Sketch Pad (VSP) was utilized. This software’s key attribute is its ease of use, which greatly reduced many of the labor-intensive modeling practices found in other CAD packages and allowed for rapid design iterations after initial analyses were completed. The concepts were base-lined against similar existing UAVs, including the MLB V-Bat and the AeroVironment Skytote. Maintenance and operation (M&O) costs for each of the Reimar concepts are calculated and compared against existing UAVs with similar payload

Analysis of Low Probability/High Consequence Risk Assessment Methods

Student: Steven Hendrickson, Graduate Student, The College of William & Mary

Mentor: Sharon Monica Jones, Aeronautics Systems Analysis Branch

There exists a need for more accommodating risk assessment (RA) methods. Past methods have failed to address all requirements of the NASA Aviation Safety and Airspace Programs. A certified and validated risk assessment method having the ability to accommodate inputs pooled from simulation results, human factors analyses, historical data, and hazard identification techniques is required. This study reviews current low-probability/high-consequence (lp/hq) risk assessment methods used in the worldwide aviation community, as well as any system that can be covered by the lp/hq umbrella. The study concludes by identifying a list of existing methods having the potential to meet NASA needs.

Exploring the use of carbon nanotubes for Vertical Takeoff and Landing (VTOL) Unmanned Aerial Vehicles

Student: Kevin R. Antcliff, Sophomore, Virginia Polytechnic Institute and State University

Mentor: Mark Moore, Systems Analysis Branch

Materials made of carbon nanotubes have been of interest to many scientists because of their remarkable characteristics. It is stiff, flexible and extremely elastic. These three characteristics make it an incredible candidate for a perfect spring that can store astonishing amounts of energy, i.e. Carbon Nanotube Springs (CNS). Current research efforts have included a literature search, interviews with technology experts, and development of the foundational objectives and approaches for investigating this use of CNS for aerospace applications. Initial efforts have been guided by understanding past attempts at achieving jump capability in insect, bird, mammal, and aircraft (yes, even aircraft have attempted to mimic nature through jumping behavior). Application analysis continues in small Unmanned Aerial Vehicles, capable of Vertical Takeoff and Landing (VTOL) through new methods of design integration using this tremendous new technology

Vehicle Sketch Pad: SACD Team Project

Student team partners:

Kevin R. Antcliff, Sophomore, Virginia Tech
Guillermo “Willie” Costa, Junior, Cal Poly, Pomona
Nachiket Desphande, Senior, Ohio State University
Edric M. San Miguel, Senior, Granby High School
Alison N. Snyder, junior, Ohio State University (Presenter)

Mentors: Mark D. Moore, William J. Fredericks, Andrew S. Hahn
Systems Analysis Branch

Vehicle Sketch Pad is modeling software that NASA employees have created to aid in modeling aircraft. Because it was created for aircraft specifically, wings, fuselages, etc. can be more accurately depicted than with traditional CAD packages. The time taken to model an aircraft is also greatly reduced, as parts such as engines, propellers, and wings can be added directly into the model. Once a part has been selected, one may modify the part, changing parameters such as thickness, airfoil, and material. Student interns were introduced to the program upon arrival and instructed to learn from the newly developed manual. After learning the ropes of the program, the interns were to revise the manual, creating a more intuitive experience for the user. Students also modeled several aircraft and aircraft parts that related to their other projects.

Software tests for Real World Design Challenge, Team Project

Students:
Matthew Anderson, Freshman, Florida Institute of Technology
Jordan Bell, Senior, Westfield High School
Edric San Miguel, Senior, Granby High School

Advisor or Mentor: Mr. Andy Hahn, Systems Analysis Branch

NASA has joined forces with others in government and industry to participate in the aviation part of the Real World Design Challenge (RWDC). In the RWDC, students from across the nation submit their designs to a specific problem generated by the RWDC aviation technical committee. Students are invited to use Pro/ENGINEER software to solve the challenge. In order to help the committee, we are testing the software to assess the learning curve for this particular program. We will also help the planners assess whether the proposed aviation challenge is open-ended. Planners believe there should be no single correct solution, that participants should have the opportunity to employ their personal strengths and creativity. By testing the software as it applies to the sample challenge, we hope to give the planners some feedback that will improve the aviation challenge before it is released to the schools.

Systems Engineering Directorate

Comparing aircraft models

Student: Amanda Huff, Junior, Western Kentucky University

Mentor: Mark Motter, Electronic Systems Branch

This project involves using both an aircraft simulation model previously developed from wind tunnel data of a full-span aileron airplane and wind tunnel data from a plane with a more complicated (16-segment aileron) wing configuration to determine whether the behavior of an aircraft with the latter configuration can be predicted using the gathered data. Comparisons are being made between the rolling moment data at varied angles of attack and aileron deflections for the full-span aileron wing, the 16-segment aileron wing mimicking the former, and the additive affect of each aileron deflected individually for the 16-segment aileron wing. After first observing the similarities between the first two configurations and making conjectures concerning any variation, this project will attempt to determine whether or not the behavior of a 16-segment aileron plane flying with ailerons at various deflections can be modeled / predicted by the additive effects of single aileron deflections.

Computational Fluid Dynamics Validation of Supersonic Retropropulsion Configurations

Student: Chris Cordell, Graduate Student, Georgia Institute of Technology

Mentor: Artem Dyakonov, Atmospheric Flight and Entry Systems

Supersonic retropropulsion is one potentially enabling technology for enhancing an entry vehicle's aerodynamic drag such that high mass systems can successfully enter low-density atmospheres and land safely. Firing jets into a supersonic flow creates a complex flowfield whose structure depends on nozzle strength, number, and location. Previous wind tunnel work indicates that the possibility exists for aerodynamic drag preservation on the vehicle while providing additional deceleration via thrust. This project aims to use computational fluid dynamics for determination of the flowfield and aerodynamic characteristics of a supersonic retropropulsion configuration and to validate the results against available wind tunnel data.

Ares-V Rapid Prototyping Design, Team Project

Students: Kevin M. Sims,
Senior, University of Arkansas at Pine Bluff
Shawn Knutson, Senior, Northern Illinois University

Mentor: Nancy Holloway, Fabrication Technology Development Branch

The purpose of the project is to design and fabricate a desktop model of the Ares-V rocket (1/10th of an inch to the foot) using Pro Engineer software, Insight software and Fused Deposition Modeling hardware. Pro Engineer is a computer-aided-design software package that allows the user to create three dimensional parts and assemblies. The CAD file is converted to a STL file using Pro Engineer. The STL file is transferred to Insight where the program will slice the part into layers that the FDM will build. Insight also adds the necessary supports and allows the user to view the tool paths and alter the position that the part is built in. The FDM uses polycarbonate to build the part. The polycarbonate softens while in the nozzle and quickly solidifies as it leaves the nozzle. In order to successfully complete the project, close attention is paid to the angle at which the parts are designed. The use of the FDM creates certain design restrictions that make modifications necessary. The build volume of the FDM makes it necessary to build the rocket in sections. The joints that connect the different sections with one another are a focal point of the project. Essentially, the use of trial and error is the method followed.

Aeronautics Research Directorate

Aeronautics Problems and Activities for Grades K-12, Team project

Students:

Matthew Anderson, Freshman, Florida Institute of Technology
Jordan Bell, Senior, Westfield High School
Eden Middleton, Senior, James Madison University

Mentor: Dr. Elizabeth Ward
Aeronautics Research Directorate & Strategic Relationships Office

This project demonstrates the application of aeronautics to four core subject areas in the standard precollege curriculum, grades Kindergarten through High School Senior. We define aviation and aero-related scenarios, problem sets, and activities that can be used to help teach math, science, language and social studies. Where applicable, the content adheres to the accepted national benchmarks for science and math standards. This effort will lead to an organized compilation of aero-focused information that will be useful to students, teachers, and homeschoolers. The problems and activities will be tested at NASA's Classroom of the Future, Center for Educational Technologies. Once approved, the content can be released in a number of formats, including web, video, and print media.

Joint Project: Using sramjet technology for space access (also listed under Science Directorate)* presented as Science Directorate

Students:

Chris Acuff, Junior, Mississippi State University
Kelcy Brunner, Junior, South Dakota School of Mines and Technology
Rita Groetz, Senior, University at Buffalo
Catherine Patrick, Senior, University of South Dakota

Mentors: Dr. Elizabeth Ward and Mr. Guy Kemmerly
Aeronautics Research Directorate & Science Directorate

With the successful flight of the X-43A scramjet at Mach 9.6 in 2004, the conceptualization of hypersonic air-breathing vehicles as a method of transportation proceeds closer to feasibility. To study the potential of scramjets, the engineering and scientific implications of scramjet use as a method of space access were explored by looking at a two-stage to orbit scenario. The chosen mission uses a preconceived reference vehicle to carry a payload into low earth orbit. Attention was focused on performing a variable weight analysis of the scramjet portion of the flight in MATLAB, studying the combustion chemistry and extrapolating the atmospheric effects associated with scramjet travel in the upper stratosphere.

Presented Last from Research and Technology Directorate:

Planar Laser-Induced Fluorescence Investigation of the Orion Crew Exploration Vehicle Reaction Control System Jets

Student: Christopher B. Ivey, Junior, Johns Hopkins University

Mentor: Dr. Paul M. Danehy, Advanced Sensing and Optical Measurement Branch

Nitric-oxide (NO) planar laser-induced fluorescence (PLIF) has been used to investigate the Orion crew exploration vehicle (CEV) reaction control system (RCS) jets in the wake of a hypersonic crossflow. The PLIF images were post-processed and imported into the Virtual Diagnostics Interface (ViDI) to coalesce with the CAD representation of the CEV to render averaged flow volumes and spatial scans. The PLIF data was compared to computational models (by creating theoretical PLIF images) and temperature sensitive paint in an effort to predict the CEV aft-body surface heating.

2009-2010 Student Opportunities
Aeronautics Research Mission Directorate

To explore student opportunities in NASA Aeronautics, visit our web site at

http://www.aeronautics.nasa.gov/education.htm

A new Fundamental Aeronautics Student contest will be announced before September 1, 2009

http://aero.larc.nasa.gov

www.nasa.gov